Spray Cooling Enhancement of Air-Cooled Condensers

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Spray Enhancement at the Crockett Power Plant

The Issue

California's population is expected to increase from 37 million today to more than 49 million by 2025.[1] Given such precipitous growth, the California Department of Water Resources anticipates a water shortfall of as much as 2.4 million acre-feet annually by 2020[2]—the amount of water required to supply 4.8 million households.

Power generation consumes 235,000 acre-feet of California's water supply per year,[3] with most of that water being used for wet cooling technologies at power plants. On average, a 500-megawatt (MW) combined-cycle power plant using wet cooling requires three million gallons of water per day, predominately for cooling.[4] In contrast, a similar-sized plant using dry cooling technology will consume only about 5% of that amount (0.15 million gallons per day).[5] The water savings, approximately 2.85 million gallons from just one power plant per day, could satisfy the daily water demands of more than 12,445 people—nearly enough to supply the needs of Auburn, California, each day.

Despite this enormous water savings, most power plants still use wet cooling—primarily because on hot days, dry cooling can lead to increased turbine back pressure that prevents a plant from generating at its full rated capacity. The problem is compounded because hot days are precisely when the state's electricity demand is the highest and electrical system reliability is at stake.

This hot-day performance problem with dry-cooled units can be alleviated by using supplemental cooling as needed. One method is to introduce a small amount of water spray into the cooling

[1] U.S. Census Bureau. Projections of the Total Population of States: 1995 to 2025. www.census.gov/population/projections/state/stpjpop.txt.
[2] California Energy Commission. January 25, 2001. "Water Supply Opportunities and Constraints for Thermal Powerplants" Draft Report: www.energy.ca.gov/siting/constraints/documents/2001-01-26_WATER_SUPPLY.PDF
[3] Ibid.
[4] California Energy Commission. July 2002. Comparison of Alternate Cooling Technologies for California Power Plants: Economic, Environmental and Other Tradeoffs. PIEREA. www.energy.ca.gov/pier/reports/600-02-dry_cooling.html.
[5] Ibid.

tower inlet air stream, where it evaporates and cools the air. Studies have shown that reducing inlet air temperature by even a few degrees can maintain much of the plant's output during hot hours. This spray enhancement technique can be retrofit on existing dry cooling units as well as installed on new units.

Spray systems have been used successfully in applications such as process coolers and gas turbine inlet air cooling, but applications have been limited. To assess the reliability and cost-effectiveness of this technique in larger cooling applications, a demonstration is needed to evaluate the technology on full-sized power plants.

Project Description

This project conducted a pilot-scale field evaluation of the performance, costs, and potential problems associated with spray enhancement for dry cooling. A key challenge for this technology is to achieve as complete evaporation of the spray as possible. Unevaporated droplets do not enhance the cooling effect but simply increase plant water use if they cannot be collected and recycled. Worse, if they are carried into the cooling system's finned tube bundles, they can cause surface scaling and corrosion. If they fall out of the air stream as "rainback," they can create a maintenance problem as well as an environmental discharge violation. Extremely fine sprays can achieve near-complete evaporation, but require a high-pressure, low-flow nozzle design that is very costly.

Accordingly, this project investigated whether a reasonably priced spray enhancement system using moderate-pressure, higher-flow nozzles could provide adequate cooling, high fractional evaporation, and acceptable "rainback" without causing scaling or corrosion of the finned tube heat exchangers.

Researchers screened 15 spray nozzles and three mist eliminators at EnviroCare International's laboratory in Napa, California, and selected three nozzles (one swirl type and two pintle type) and one demister design for field testing. Field testing occurred on a single cell of a full-size Balcke-Duerr air-cooled exchanger at the Crockett Cogeneration Facility, a 240-MW gas-fired, combined-cycle plant in Crockett, California. This single-cell testing helped determine the effects of ambient meteorology, spray droplet size, spray flow rate, and nozzle location on inlet cooling and efficiency of water use.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing reliable energy.** Spray enhancement would enable dry-cooled power plants to produce more power on hot days—thereby increasing electrical system reliability during peak demand periods. Moreover, by alleviating dry cooling's hot-day capacity/efficiency penalty, the spray enhancement technique promotes wider penetration of dry cooling—a technology that increases siting options by allowing power plants to be built closer to end users in areas where water is in short supply.
- **Providing environmentally sound energy.** Dry cooling significantly reduces fresh water use, leaving more fresh water in the natural environment or available for delivery to customers.

- **Providing affordable energy.** Given California's burgeoning population and limited water supply, power plant operators will find themselves in strict competition with other water-consuming sectors. Water costs will rise, increasing the cost of electricity. Dry cooling can help power producers keep down their costs of production.
- **Providing safe energy.** Dry cooling systems can alleviate potential public health and safety issues by reducing potential surface and groundwater contamination, salt deposition from cooling tower drift, Legionnaire's Disease, vapor emissions from volatile organic chemicals, and trihalomethane exposure.

Results

Field tests yielded the following conclusions:

- The cooling effect ($T_{ambient}$–T_{inlet}) was a strong function of ambient wet bulb depression ($T_{amb\ dry\ bulb}$–$T_{amb\ wet\ bulb}$) and spray flow rate.
- The cooling effect ranged from 60% to nearly 100% of the prevailing wet bulb depression, depending on spray rate and ambient conditions.
- With ambient temperature >90°F and relative humidity <40%—i.e., under conditions when spray enhancement would most likely be used—a cooling effect of 80% or more of the wet bulb depression could be expected.
- The effects of spray droplet size distribution and nozzle location (droplet residence time) were discernible but typically minor.

The initial cost of a full-scale inlet air-cooling system for a 30-cell air-cooled condenser (intended to approximate the size found at a typical 500-MW combined-cycle plant, the type currently proposed for development in California), with a performance capability of reducing the inlet air temperature by 30°F under the hottest conditions, was estimated at $600,000. Assuming spray enhancement recovers 75% of the output loss during the 1000 hottest hours of the year, the payback period for a "desert" installation (e.g., Blythe, California) ranged from less than a year to two and half years, depending on the assumed price of peak power.

Final Report

The final report is posted at http://www.energy.ca.gov/reports/2004-03-09_500-03-109.PDF.

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